285-47 AU 353 47911
GB 2021230
NOV 1979

(12) UK Patent Application (19) GB (11) 2 021 230 A

(21) Application No 7914797
(22) Date of filing 27 Apr 1979
(23) Claims filed 27 Apr 1979
(30) Priority data
(31) 58272
61275
73121
(32) 28 Apr 1978
8 May 1978
30 May 1978
(33) Japan (JP)
(43) Application published
28 Nov 1979
(51) INT CL²
F16L 59/05
(52) Domestic classification
F2P 1A35 1A9 1B1 1B3
1B5D 1B6 1B7 1B8
(56) Documents cited
GB 1380686
GB 1378110
GB 1327533
GB 884119
(58) Field of search
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F2X
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(54) Heat insulation systems

(57) A heat insulation system for low temperature pipe lines comprises a plurality of cylindrical heat-insulating units A, A' tightly cover the outer periphery of a pipe line 1. Each unit includes a heat-insulating arcuate element 2 of a foamed synthetic resin, bonded to an elastic layer 3 capable of accommodating strain caused by contraction of the element 2 at low temperature. A thin metal plate 4 is bonded to layer 3 as an outer sheath. A sealing means B is applied to joint contact surfaces of the adjacent heat-insulating units. This system can easily be fabricated, conveyed to the place where pipe lines are installed, and assembled in situ at a low cost. Delamination of the metal plate 4 is prevented by the elastic layer 3.

FIG. 1

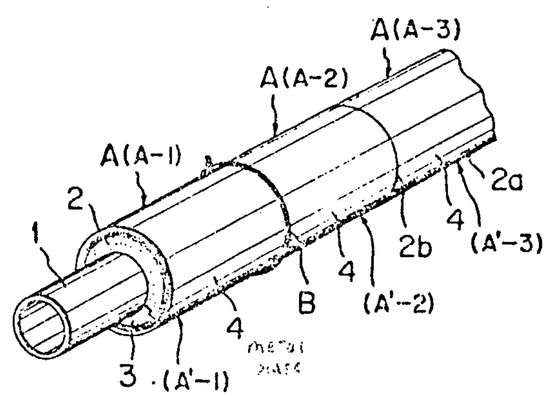

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FIG. 1

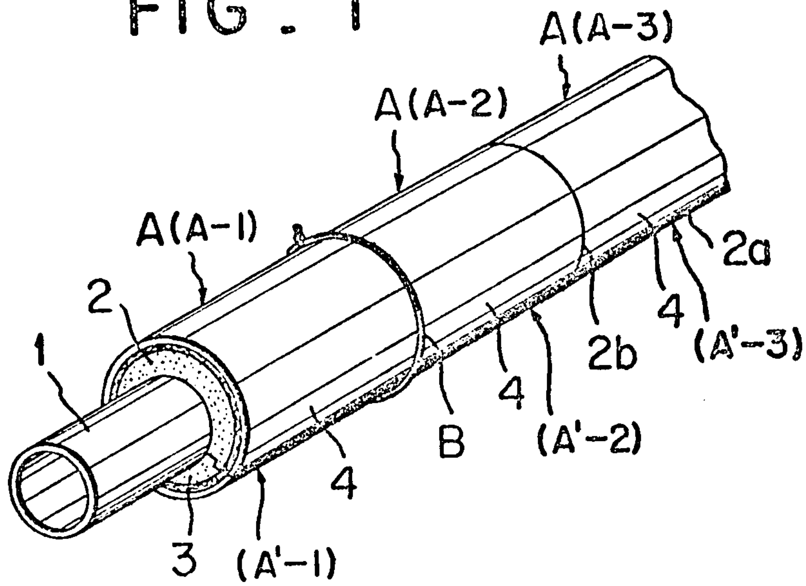


FIG. 2

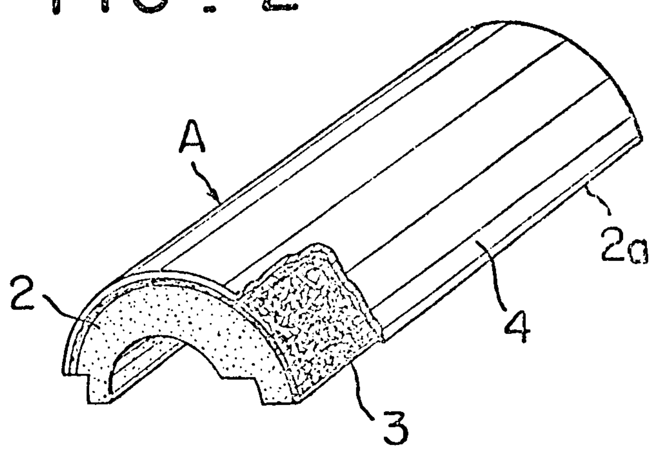


FIG. 3

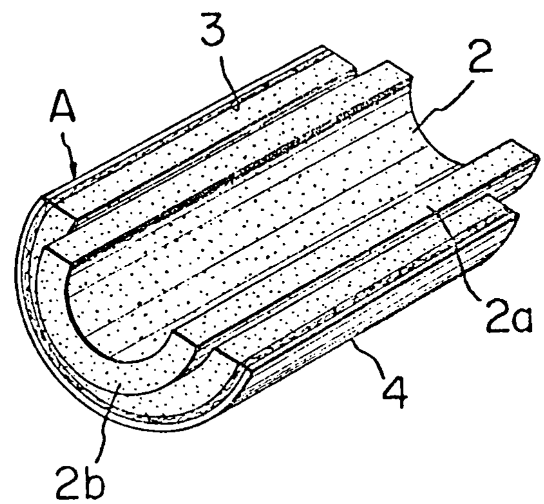


FIG. 4

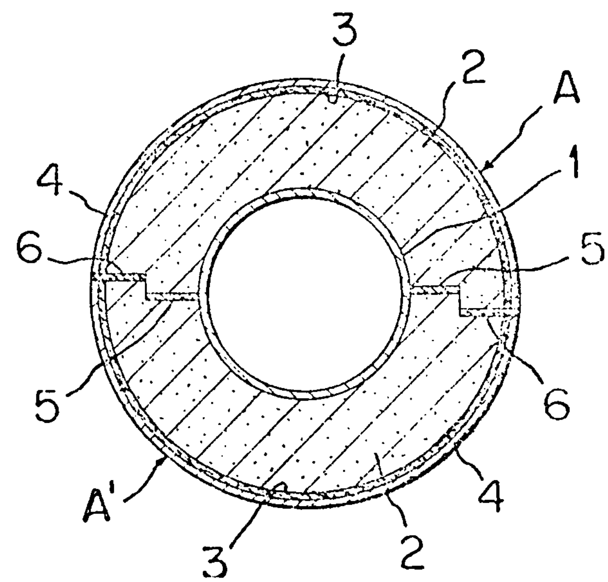


FIG. 5

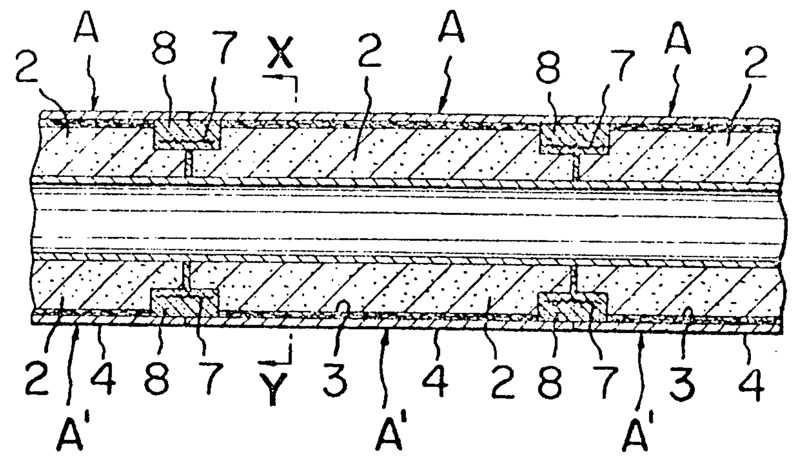


FIG. 6

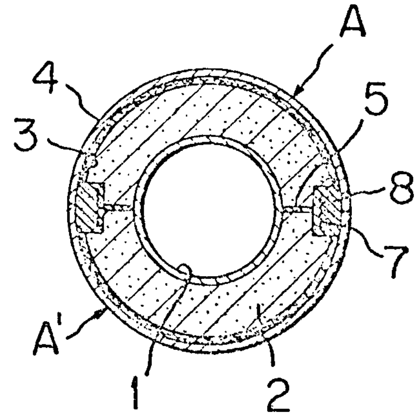


FIG. 7

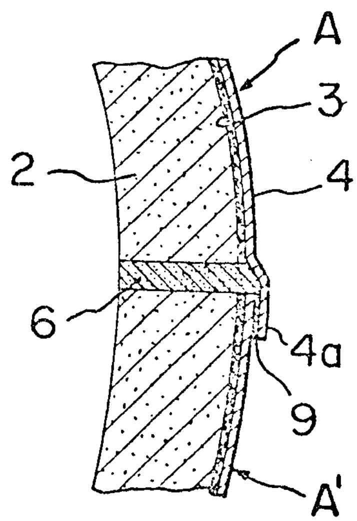


FIG. 9

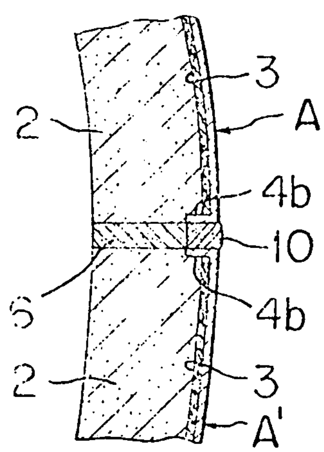


FIG. 8

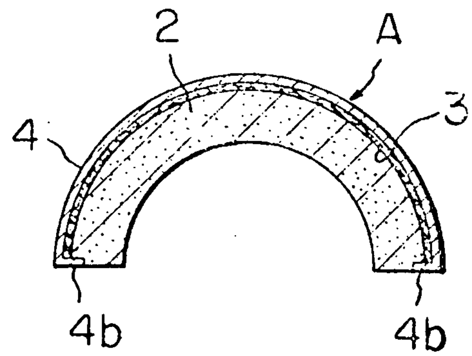


FIG. 11

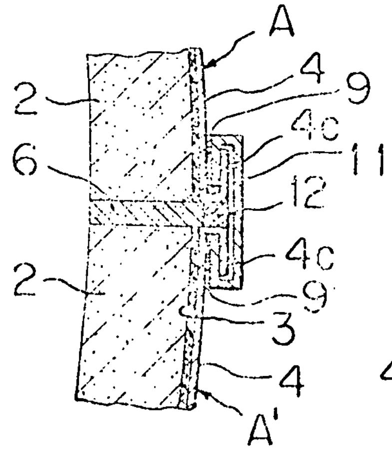
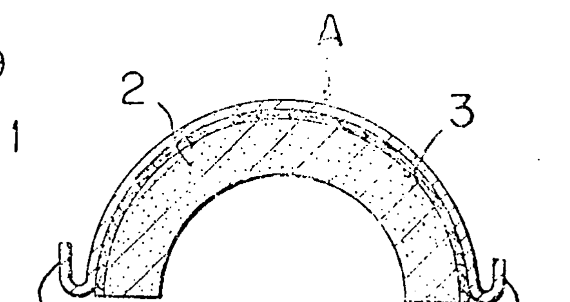


FIG. 10



SPECIFICATION

Heat insulation systems

This invention relates to heat insulation systems. It is applicable to the insulation of pipe lines for transportation of low temperature fluids such as LPG, LEG, LNG and the like liquefied gases.

In the past, conventional heat insulation systems for pipe lines of this type have used rigid polyurethane foam shaped into an arcuate panel as heat-insulating units. Because of its excellent workability and heat-insulating property, a heat insulator made of rigid polyurethane foam was considered to be suitable for insulating pipe lines for transporting a fluid kept at a temperature as low as between −100 and −200°C.

A practical method for constructing such heat insulation system comprises assembling a plurality of the heat-insulating panel elements with arcuate cross section to form cylindrical heat-insulating assemblies arranged in series on the outer periphery of a pipe, applying, if necessary, a joint sealer to the joint contact surfaces of the adjacent assemblies, fixing the heat-insulating assemblies around the pipe by a fixing means such as an adhesive, an adhesive tape, wires or steel bands, applying a layer of a moisture-proof material such as mastic or a water-repellent sheet onto the surface of the heat-insulating assemblies and winding a thin metal plate such as a zinc- or resin-coated iron plate onto the layer as a protective sheathing.

However, such a heat-insulating system is disadvantageous in that it requires hard labour and incurs considerable costs and time for construction. In order to overcome such defects, an attempt was made to simplify the construction of the system by binding a thin metal plate onto the outer surface of each heat-insulating panel element having arcuate cross section and made of a foamed synthetic resin with the aid of an adhesive or by utilising self-adhesiveness of the foamed synthetic resin. A thin metal plate behaves very well as a moisture-proofing and sheathing material, but the metal has a coefficient of expansion which is significantly different from that of the foamed synthetic resin. Such a difference produces partial delamination of the thin metal plate from the heat-insulating element made of the foamed synthetic resin, thus forming wrinkles on the metal plate due to the stress caused by contraction of the foamed synthetic resin at a low temperature during transporting of supercooled fluid through the pipe line. When such wrinkles are formed in the joint contact surfaces (referred to hereinafter simply as the joint portion) between adjacent cylindrical heat insulating units, moisture and water will enter through the wrinkled joint portions to worsen the heat-insulating ability and, in the extreme case, breakage of the insulator will occur as a result of expansion of the water by freezing, with the result that the function as heat-insulating system be seriously damaged to incur a considerable loss.

Since the foamed synthetic resin contracts more at low temperatures than the transportation pipe, interstices or voids will be formed in the joint portion between the adjacent heat-insulating units, especially in case of pipe lines kept at an extremely low temperature, whereby permeation of moisture and water as well as thermal short circuits will occur through the damaged joint portions. Furthermore, breakage or rupture of the insulator itself will take place on freezing of the permeated water.

To overcome such drawbacks, a method has been proposed in which a refractory coating material, such as foamed glass, heat-shielding material made of calcium silicate or pearlite or asbestos plate, previously processed to have a desired shape, is mounted on the outside of a foamed synthetic resin heat-insulating element at the same time or after application of the foamed synthetic resin insulating material and finally a thin outer metal plate is applied to protect the refractory material and to provide an attractive appearance (Japanese Patent Publication No. 17871/68 and Japanese Utility Model Publication No. 4386/71). However, this method involves such drawbacks that many difficult manufacturing steps are needed for shaping the refractory coating material and conveying the shaped article to the place where the heat insulator system is constructed. Since such refractory material is brittle, loss of the material caused by mechanical damage during the transportation and construction is by no means negligible and high costs are incurred. Thus, an improved refractory coating material was proposed to overcome such drawbacks wherein previously shaped pearlite refractory material was bound with a double adhesive tape (Japanese Utility Model Publication No. 10391/71). However, this refractory coating material also involves such technical and economical disadvantages that it is practically impossible to bind the pearlite refractory material and the foamed synthetic resin insulating material with an adhesive tape so as to exert a binding strength strong enough for handling. As a result, even if both materials are bound temporarily, both materials will be separated while being conveyed or used for construction of the insulator, and further application of a moisture-preventing material and a top-covering material is needed.

In the field of heat insulators for pipe lines, therefore, there is a great demand for developing a heat insulator not only better in moisture-proofing and heat-insulating properties but also resistant to delamination due to shrinkage of the foamed synthetic resin at low temperatures.

According to one aspect of the invention, there is provided a heat insulation system for a low temperature pipe line, the system comprising a plurality of cylindrical heat-insulating assemblies disposed sequentially along the outer surface of the pipe line, each assembly including a layer of a foamed synthetic resin material, a deformable layer bonded to the outer surface of the foamed layer, and a thin metal plate bonded to the outer surface of said deformable layer, sealing means being applied to joint contact surfaces of the adjacent assemblies, and said deformable material being so deformable and having a recovery characteristic such that it is capable of accommodating strain caused by differential contraction of said foamed layer and said metal plate.

According to a further aspect of the invention, there is provided a heat insulation system for pipe lines for transportation of low temperature fluids which comprises a plurality of longitudinally divided hollow cylindrical heat-insulating assemblies arranged to cover the outer periphery of said pipe lines, wherein each heat-insulating assembly comprises: at least one heat-insulating element made of a foamed synthetic resin material overlaid by and bonded to an elastic deformable layer capable of absorbing strain caused by shrinkage of said heat-insulating element at low temperature there being a thin metal plate bonded to the outer surface of said deformable layer, and wherein a sealing means is applied to longitudinal and transverse joint contact surfaces of the adjacent heat-insulating assemblies.

For a better understanding of the invention, and to shown how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:—

Figure 1 is a perspective view of one embodiment of heat insulator system;

Figure 2 is a perspective view of a semi-cylindrical heat insulating unit of the system shown in Figure 1, the unit being partially broken to show an elastic sheet;

Figure 3 is a perspective view of another example of semi-cylindrical heat insulating unit;

Figure 4 is a cross-sectional view of the heat insulator shown in Figure 1;

Figure 5 is a longitudinal-sectional view of another embodiment of the heat insulator;

Figure 6 is a cross-sectional view of the heat insulator shown in Figure 5 cut along the line X—Y;

Figure 7 is a partial enlarged cross-sectional view of one example of a joint portion of the heat insulating unit;

Figure 8 is a cross-sectional view of a further example of a semicylindrical heat insulating unit;

Figure 9 is a partially enlarged cross-sectional view of a joint portion of the heat insulating unit shown in Figure 8;

Figure 10 is a cross-sectional view of further example of a semi-cylindrical heat insulating unit: and

Figure 11 is a partially enlarged cross-sectional view of a joint portion of the heat insulating unit shown in Figure 10.

In Figure 1, a pipe 1 for transportation of an extremely low temperature fluid is provided with a heat insulator composed of a plurality of longitudinally divided cylindrical heat-insulating units *A* (A—1, A—2, A—3, etc) arranged sequentially to cover the pipe 1 over its full length. Since each heat-insulating unit *A* is arcuate in cross section, two or more units (e.g. A, A') are first combined in the transverse direction of the pipe line to form a complete hollow cylindrical heat-insulating assembly as a minimum unit for constructing a series of the heat-insulating units arranged to cover the whole outer periphery of the pipe 1 over its full length. Each heat-insulating unit is preferably semi-cylindrical in shape so that a pair of them (A—1 and A'—1, A—2 and A'—2; etc.) is used for the construction of each heat insulator assembly.

The heat-insulating assembly may be in a hollow cylindrical form through which the pipe 1 is inserted. However, a heat-insulating unit of this type is extremely inconvenient in practical use because the pipe lines have to be covered originally with the heat-insulating assemblies of this type prior to the installation of the pipe lines. Where the heat insulator is composed of a plurality of longitudinally divided hollow cylindrical heat-insulating units, the insulator can readily be assembled to cover the pipe lines after it has been installed.

A fastening means *B* may be used to secure complete fixing of the heat insulator to the pipe 1. However, the use of such fastening means *B* may be omitted if an adhesive used for binding the adjacent heat-insulating units is strong enough. Any conventional fastening means such as a rope, wire, belt, tape or chain furnished with a mechanical fastening member can be used as the fastening means *B*.

The length and thickness of the heat insulator depend on the diameter and length of the pipe line to be protected and on the temperature of the fluid passed therethrough. Usually, the length of the heat insulator can be adjusted by increasing or decreasing the number of the heat-insulating assemblies arranged in series. In general, a heat-insulating unit having a thickness of 20 to 300 mm and a length of 0.1 to 10 m is preferable. When the pipe line is curved or branched, each heat-insulating unit, in compliance with such geometrical shapes can easily be manufactured by moulding or a like shaping method.

In Figure 2 showing the structure of a preferred example of the heat-insulating unit *A*, a heat-insulating panel element 2 of a semi-cylindrical shape made of a foamed synthetic resin is overlaid with an elastic sheet 3 which is further overlaid with a thin metal plate 4.

As seen in figure 1, a pair of the semi-cylindrical heat-insulating units (A—1 and A'—1) constituting a hollow cylindrical form is then combined with another pair of the units A—2 and A'—2, and other plural pairs of the units are arranged in series on the periphery of the pipe 1 whereby the individual units are combined with the adjacent ones at their longitudinal joint surfaces 2—a and their semi-cylindrical transverse joint surface 2—b. The insulator composed of a plurality of the heat-insulating units is fixed to the pipe at several points by a fixing means B for securing the cylindrical insulating units, e.g. a pair of the facing semi-cylindrical insulating units A and A'.

Examples of the foamed synthetic resin used for the heat-insulating panel element 2 include foams of polyisocyanate series such as a rigid polyurethane foam and polyisocyanurate foam, and cold-resisting foams such as an epoxy resin foam, a phenol resin foam or polystyrene foam. These foamy substances possess excellent heat-insulating property at low temperatures.

The panel element 2 can easily be obtained by any of the techniques known per se in the field of polymer chemistry e.g. according to a method in which a block of a foamed resin such as a rigid polyurethane foam is cut into a desired shape, a method wherein a liquid foamable synthetic resin is charged into a mould of the desired shape and foamed in the mould and thereafter the moulded article is released from the mould, and a method in which a liquid foamable synthetic resin is sprayed over the surface of a rotating core and allowed to foam to make a foamed resin layer of predetermined thickness, and then the long hollow cylindrical foamed resin thus obtained is removed from the core and cut lengthwise into at least two portions of arcuate cross section.

The panel element 2 may have on its inner surface a layer of a reinforcing material such as a sheet, woven or knitted fabric, non-woven fabric or a low-foamed synthetic resin (so-called "skin of the foam"). Furthermore, the panel element 2 may be embedded with one or more layers of such reinforcing material for enhancing mechanical strength of the heat-insulating unit *A*. The low-foamed synthetic resin as a reinforcing material is obtained without any further treatment when the heat-insulating unit *A* is manufactured in one operation by moulding. When the reinforcing material is a fabric or the like fibrous material, it can conveniently be bonded to panel element 2 by the aid of a low temperature adhesive or by utilising self-adhesiveness of the synthetic resin at the stage of its foaming and solidification. The use of one or more layers of the reinforcing material or materials can improve the mechanical strength and dimensional stability of the arcuate panel element 2 and permits the use of a low density foamed synthetic resin, thus serving to reduce the production cost of the heat-insulating unit *A*.

Illustrative of the elastic material utilisable for the elastic sheet are, for example, plastic foams or foamed rubbers with a specific gravity of approx. 0.02 to 0.5, e.g. a soft polyurethane foam, a semi-rigid polyurethane foam or a soft polyvinyl chloride foam. Also utilisable as the elastic sheet 3 are elastic sheets manufactured from inorganic fibres such as ceramic fibres, rock wool, glass wool, asbestos fibres or a mixture thereof formed with the aid of a small amount of a binder or merely by intertwining the fibres without the use of any binder. These sheets are generally known as felt, blanket, board and paper of inorganic material. In addition, bulky woven fabrics or braids made of the above-described inorganic fibres may be used.

The elastic sheet 3 preferably has a thickness of 1 to 10 mm. The use of an elastic sheet made of inorganic fibres is also preferable because of its fire-resisting properties. It is preferred that such fire resistant elastic sheets have a specific gravity of 0.1 to 0.5 g/cm^3 and a thickness of 5 to 20 mm. These sheets are bonded integrally to the thin metal plate 4 by a rubber adhesive, polyurethane adhesive or an epoxy resin adhesive.

Examples of the thin metal plate 4 include an anti-corrosive iron plate such as a zinc-coated iron plate or a resin-coated iron plate, an aluminum plate and a stainless steel plate having a thickness of about 0.1 to 1 mm.

The heat-insulating unit *A* including the elastic sheet 3 interposed between the heat-insulating panel element 2 and the thin metal plate 4 can be fabricated, for example, according to the following compression moulding method: A thin metal plate 4 such as an aluminum plate to which an elastic sheet 3 such as a felt of an inorganic fibrous material has previously been fixed by the aid of an adhesive containing as a main component thereof a polyurethane, an epoxy resin, an epoxyacrylate resin, a vinyl acetate resin or a synthetic rubber, is placed in a female mould in such manner that the thin metal plate is faced to the inner surface of the female mould. A liquid foamable synthetic resin capable of exerting self-adhesiveness when foamed and solidified is then poured into the mould. A male mould is set in position and, after completion of the foaming and solidification operation, the resulting moulded article is taken out from the mould. A heat-insulating unit having a desired shape can thus be obtained, including the foamed resin heat-insulating element 2 covered with the elastic sheet 3 as intermediate layer and a water- and moisture-proof thin metal plate 4 as outermost layer. In this moulded product, the surface of the foamed synthetic resin, i.e. the heat-insulating panel element 2, which was brought into contact with the inner surface of the male mould, forms a hard skin and functions as a layer of the reinforcing material. Alternatively, the above moulding operation may be carried out while holding a reinforcing material in the form of a sheet, a woven or non-woven fabric, a braid, a net or a bulky net structure temporarily on the inner surface of the male mould whereby this reinforcing material is fixed onto the inner surface of the heat-insulating unit *A* in a single step by virtue of self-adhesiveness of the foamed synthetic resin. Similarly, the heat-insulating unit involving the panel element 2 embedded with one or more layers of the reinforcing material or materials can be obtained in one step by holding the layer or layers in the female mould when the liquid foamable synthetic resin is poured thereinto.

The heat insulating unit *A* may be fabricated according to the following alternative method. A mould-releasing agent is applied onto a tubular or rod-like core having an outer diameter corresponding to that of a pipe for transportation of a low temperature fluid. If desired, a reinforcing material of the type above mentioned is then wound around the core. The core is then rotated, and during the rotation a liquid foamable synthetic resin is sprayed over the core surface covered with the mould-releasing agent alone or further with the reinforcing material by a spraying device having a mechanism for moving a spray head along a line parallel to the axis of the core at constant speed. The foamable resin thus applied is then allowed to foam, is solidified and is removed from the core to obtain a cylindrical foamed resin heat-insulating element. The elastic sheet 3 and the thin metal plate 4 are successively applied to and fixed on the cylindrical heat-insulating element 2 by the aid of an adhesive of the type already described. As an alternative, the elastic sheet 3 and the thin metal plate 4 may be integrally combined with the cylindrical heat-insulating element 2 on the core before it is removed therefrom. In this spraying method, it is possible to manufacture a cylindrical heat-insulating unit having one or more reinforcing layers on the inner surface and/or the inside thereof, for example, by first applying a foamable synthetic resin by spraying onto a coating of the mould-releasing agent around the periphery of the core or the surface of the reinforcing material wound on the periphery of the coating until the thickness of the foamable resin reaches a predetermined value, interrupting the application of the resin at this stage, allowing the applied resin to foam, winding an additional reinforcing material around the surface of the resin after its solidification, again applying the foamable resin onto the additional reinforcing material until the thickness of the applied resin reaches a predetermined value whereby the resin is permeated in the additional reinforcing material and finally allowing the secondly applied resin to foam and repeating this cycle prior to applying the elastic sheet and the thin metal plate. The hollow cylindrical heat-insulating unit thus obtained is removed from the core and then cut lengthwise into at least two portions, each showing a circular arcuate cross section and corresponding to the heat-insulating unit as shown in Figure 2. This method is particularly suitable for obtaining the heat-insulating unit *A* embedded with one or more layers of the reinforcing material or materials.

In a variant of the first-mentioned method, the heat insulating unit *A* is fabricated by shaping a bun stock of a foamed synthetic resin with excellent low temperature characteristics, e.g. a polyisocyanate-base foamed synthetic resin such as a rigid polyurethane foam or a polyisocyanurate foam, an epoxy resin foam, a phenolic resin foam, or a polystyrene foam, into a heat-insulating element 2 of a desired form and bonding thereto the elastic sheet 3 and the thin metal plate 4 by the aid of a suitable adhesive. In this case, the reinforcing material may also be applied to the inner surface of the insulating element 2.

In the fabrication of the heat insulating unit *A* by entirely covering the surface of the foamed resin heat-insulating element 2 with the elastic sheet 3 and then with the thin metal plate 4, it is desirable that the elastic sheet 3 be completely covered by the heat-insulating element 2 and the thin metal plate 4. This is advantageous because entrance of any foreign matter into interstices or voids of the elastic sheet 3 during transport and handling of the heat insulating unit *A* can thus be prevented.

In practice, a group of the heat insulating units *A* (a pair of the semicylindrical ones as shown in Figure 1) are assembled to surround the pipe 1 and a plurality of such groups or pairs of the units *A* are similarly arranged in series in the lengthwise direction of the pipe 1. Although a pair of the parallel, longitudinally extending side faces and a pair of the opposite, half ring side faces of the individual heat-insulating unit *A* can be made flat, it is preferred that the longitudinal side faces 2a be stepped as shown in Figure 2 so as to facilitate assembling the units and to improve the sealing effect between the pair of the units. More preferably, both of the longitudinal side faces 2a and the opposite side faces 2b of the unit *A* are stepped with a view to achieving more improved sealing effects.

In Figure 3, the structure of the unit *A* is shown in which both of the faces 2a and the faces 2b are stepped. The joint portions between the adjacent heat-insulating units are sealed with a joint sealer, a foaming adhesive such as a polyurethane foam-yielding prepolymer or other kinds of liquid foaming synthetic resin. These sealing agents are well known and easily commercially available. In case the temperature of the fluid to be transported through the pipe line is relatively high, each butt joint portion may be sealed with any of the above-mentioned sealing agents. On the other hand, in case the heat insulator system is used at a ultra-low temperature, each joint surface is preferably stepped to form two separate sections and the inner section (or the lower temperature section) is packed under pressure with a heat insulating material having good compression stability while the outer section (or the higher temperature section) is packed with a moisture-proof, heat-insulating material.

In Figure 4 showing the cross section of the stepped joint surface of a pair of the heat-insulating units A and A', the reference numerals 1, 2, 3 and 4 have the same meanings as given above but 5 represents a heat-insulating material having a good compression stability and 6 represents a heat-insulating material possessing good moisture-proofing properties. Such heat-insulating and sealing materials are selected from the conventional sealing agents, taking the operation temperature and the properties of the agents into consideration.

As the heat-insulating element is greater in shrinking ratio than the metal pipe at an extremely low temperature, conventional heat insulator systems have the drawback that cracks or voids are apt to be formed in the joint portions of the insulator units, giving a serious adverse influence on the performance of the system. In the prior art system, a countermeasure was made to overcome such technical disadvantages by the use of a multi-layer heat-insulating unit. This multi-layer heat-insulating system was, however, poor in efficiency and economy.

In contrast, the heat insulating units described here are sealed in the jointed portion by the above described special means, so that if the heat insulating element 2 undergoes shrinkage at an extremely low temperature in the course of transporting low temperature fluid, the heat-insulating material 5 with a good compression stability compressively packed in the inner section expands and absorbs stress caused by the shrinkage of the element 2, thus helping to prevent the occurrence of cracks or breakages in the joint portions. Further, the moisture-proof heat-insulating material 6 packed in the outer section concurrently serves as a water- and moisture-proof material. The heat insulator can exhibit high heat-insulating effects which cannot at all be expected in the case wherein a conventional sealer is used in a usual manner.

Illustrative of the heat-insulating material 5 are, for example, glass fibres, rock wool, ceramic fibres and the like refractory fibrous materials. These materials are usually in a bulky form or may be in the form of felt or blanket. This material is desirably packed under such condition that it is compressed to between 30 and 70% of its original volume.

The moisture-proof heat-insulating material 6 packed in the outer section of the joint portion may be non-rigid since this section is almost maintained at normal or ambient temperature. Illustrative of the moisture-proof heat-insulating material 6 are, for example, softly foamed synthetic resins of a closed cellular structure such as polyethylene foam and polyvinyl chloride foam, and foamable adhesives such as of polyurethane resin or silicone resin.

In Figures 5 and 6, showing another embodiment of the heat insulator, the heat-insulating element 2 of each heat-insulating unit is provided with a notch at each of its four outer corners so as to form a recess when the two facing units are combined. Each recess is packed with a reinforcing material 7 and then charged with a liquid foamable synthetic resin 8 which shows self-adhesiveness on foaming and solidification, e.g. a foamable semi-rigid or rigid urethane resin. The resin is foamed and solidified in the recess to make the joint portion moisture-proof and heat-insulating whereby the heat-insulating element 2, the reinforcing material 7 and the foamed synthetic resin 8 are combined integrally.

Since a liquid foamable synthetic resin is charged into the recesses of the heat-insulating element 2, foamed and then solidified, the elements are bonded strongly to each other so that the heat-insulating units can be fixed around the pipe 1 without the use of any fastening means B. The size of the recess formed in the heat-insulating element may suitably be determined taking the diameter of the transportation pipe and the temperature of the fluid into consideration. In general, the recess has a depth of 40 to 60% of the thickness of the insulating unit and a width of about 20 to 100 mm.

The side faces of the heat insulating element 2 may have the same or different shape. The side faces are not limited to those described hereinbefore but may be of any shape suitable for jointing purposes.

The reinforcing member 7 may be the same as used in the heat-insulating element 2 and may be any of the woven or non-woven fabrics, braids and net-like materials formed from glass cloth, roving cloth, chopped strand or the like fibrous materials through which the foamable liquid of the synthetic resin 8 is permeable. The exposed surfaces of the joint portions of the insulating element 2 may be left as they are or may be provided with a conventional coking material.

In Figure 7, the thin metal plate 4 of a heat-insulating unit A is arranged to have an extension 4a which is placed on the metal plate of the other heat-insulating unit A'. A non-curable sealant 9 such as a joint sealer may be applied into the interstice between the extension 4a and the thin metal plate to prevent any penetration of moisture.

In Figures 8 and 9, the thin metal plate 4 is extended at both terminal edges to have two extensions 4b which are bent toward the side face to be jointed. A coking material 10 such as a silicone or a polysulphide is packed into the space between the bent plates of the facing units A and A' to prevent penetration of moisture.

In Figures 10 and 11, the thin metal plate 4 is arranged to have two outwardly bent portions 4c at its terminal edges. A joint member 11 is slidably provided to interconnect the outwardly bent portions of the adjacent units A and A' and the space therebetween is filled with a filler 12, which is preferably moisture-resistant for improving the sealing effect of the joint portions between the heat-insulating units.

Thus the heat insulator which has been described is distinguished by interposing the elastic sheet 3 between the heat-insulating element 2 and the thin metal plate 4 whereby stress caused by contraction of the panel member at a low temperature is absorbed in the elastic sheet to prevent any delamination of the thin metal plate. In addition, the use of a specific sealing means prevents entrance of foreign matter, especially moisture, into the heat insulator, thus making it possible to use the insulator for a prolonged period of time without damage. These technical merits are remarkable and not to be expected from the conventional art.

The heat insulator is furthermore simple in structure and is easily fabricated, conveyed to the place where pipe lines to be protected are installed, and assembled in situ at a low cost.

The embodiments shown hereinbefore and described in detail are to be considered only as illustrative. It will be apparent to those skilled in the art that numerous modifications may be made without departure from the scope of the invention.

CLAIMS

1. A heat insulation system for a low temperature pipe line, the system comprising a plurality of cylindrical heat-insulating assemblies disposed sequentially along the outer surface of the pipe line, each assembly including a layer of a foamed synthetic resin material, a deformable layer bonded to the outer surface of the foamed layer, and a thin metal plate bonded to the outer surface of said deformable layer, sealing means being applied to joint contact surfaces of the adjacent assemblies, and said deformable material being so deformable and having a recovery characteristic such that it is capable of accommodating strain caused by differential contraction of said foamed layer and said metal plate.

2. A heat insulation system for pipe lines for transportation of low temperature fluids which comprises a plurality of longitudinally divided hollow cylindrical heat-insulating assemblies arranged to cover the outer periphery of said pipe lines, wherein each heat-insulating assembly comprises: at least one heat-insulating element made of a foamed synthetic resin material overlaid by and bonded to an elastic deformable layer capable of absorbing strain caused by shrinkage of said heat-insulating element at low temperature there being a thin metal plate bonded to the outer surface of said deformable layer, and wherein a sealing means is applied to longitudinal and transverse joint contact surfaces of the adjacent heat-insulating assemblies.

3. A system according to claim 2 wherein each said element is semi-cylindrical.

4. A system according to claim 1, 2 or 3 wherein each heat-insulating assembly has a circular cross-section.

5. A system according to any one of claims 1 to 4 wherein said foamed synthetic resin material is a rigid polyurethane foam, a polyisocyanurate foam, a phenolic resin foam, an epoxy resin foam or polystyrene foam.

6. A system according to any one of claims 1 to 5 wherein each said assembly includes at least one heat insulating element shaped by cutting a foamed synthetic resin bun stock.

7. A system according to any one of claims 1 to 5 wherein each said assembly includes a heat insulating element shaped by placing said thin metal plate to which said deformable layer has been bonded in a female mould, pouring a liquid foamable synthetic resin into said mould, allowing the resin to foam, and releasing the moulded article from the mould after solidification of said resin.

8. A system according to any one of claims 1 to 5 wherein each said heat-insulating assembly has been shaped by spraying a liquid foamable synthetic resin over a rotating core coated with a mould-releasing agent until the thickness of a foamed resin layer reaches a predetermined value, applying said deformable layer and said thin metal plate onto the foamed synthetic resin layer, removing the cylindrical heat-insulating assembly from said core and thereafter cutting said assembly lengthwise into at least two elements.

9. A system according to any one of claims 1 to 8 wherein each said heat-insulating assembly is provided on its inner surface with a layer of a reinforcing material.

10. A system according to any one of claims 1 to 9 wherein each said heat-insulating assembly is embedded with at least one layer of a reinforcing material in a desired position in the thickness direction.

11. A system according to any one of claims 1 to 10 wherein said deformable layer is made of a polyurethane foam, a polyvinyl chloride foam, or a rubber foam.

12. A system according to any one of claims 1 to 10 wherein said deformable layer is of felt, blanket, board or paper, or a bulky fabric or braid, which has been made of fibres of a ceramic, rock wool, glass, asbestos, or a mixture thereof, either with the aid of a small amount of a binder or by intertwining the fibres without any binder.

13. A system according to any one of claims 1 to 12 wherein said metal plate is an anti-corrosive zinc-coated steel plate, an anti-corrosion resin-coated steel, an aluminium plate or a stainless steel plate.

14. A system according to any one of claims 1 to 13 wherein said deformable layer is bonded to said metal plate with an adhesive having as a main component a polyurethane resin an epoxy resin, an epoxy acrylate resin, a vinyl acetate resin or a synthetic rubber.

15. A system according to claim 14 wherein said deformable layer is fixed to said metal plate by an elastic foamable urethane adhesive.

16. A system according to any one of claims 1 to 15 wherein said foamed layer is bonded to said deformable layer by self-adhesiveness of said foamable synthetic resin during its curing to produce foaming.

17. A system according to any one of claims 1 to 15 wherein said foamed layer is bonded to said deformable layer by an adhesive which is a polyurethane resin, an epoxy resin, an epoxy acrylate resin, a vinyl acetate resin or a synthetic rubber.

18. A system according to any one of claims 1 to 17 wherein each said element is joined to a further said element along a joint which has an inner, lower temperature zone provided with a heat-insulating material having good compression stability at low temperatures and an outer, higher temperature zone provided with a heat-insulating material which is resistant to moisture permeation.

19. A system according to claim 18, wherein each said element has a stepped formation for forming said joint, two surfaces of said stepped formation bounding respective ones of said inner and said outer zones when said joint is formed.

20. A system according to claim 18 or 19, wherein said heat-insulating material with good

compression stability at low temperature is a sheet of a felt, blanket, board or paper which has been formed from ceramic fibres, rock wool, glass fibres or a mixture thereof with the aid of a small amount of a binder or by intertwining these fibres without any binder.

21. A system according to claim 18, 19 or 20, wherein said moisture-proof, heat-insulating material has a closed cellular structure and is a polyethylene foam, a PVC foam, a polyurethane foam, or a silicone foam.

22. A system according to any one of claims 1 to 21 where each said assembly includes at least two heat insulating elements, wherein each element is provided with a notch at each outer corner so as to define respective recesses when two said elements are combined, reinforcing material and a foamed synthetic resin being provided in each recess thereby to form a sealed joint.

23. A system according to claim 22, wherein said foamed synthetic resin provided in each recess exhibits self-adhesiveness on foaming and solidification, has a closed cellular structure and is a polyurethane, a polyisocyanurate, an epoxy resin or a silicone RTV foam.

24. A system according to claim 22, wherein said reinforcing material is capable of being permeated with said liquid foamable synthetic resin exhibiting self-adhesiveness and is selected from woven or non-woven fabrics, braids and net-like materials made of glass fibres, asbestos, and metal fibres.

25. A system according to any one of claims 22 to 24 wherein each sealed joint is covered with a coking material.

26. A system according to any one of claims 1 to 21 wherein said metal plate is in at least two parts each having a part extending from one edge and bent over a face of an element of the associated assembly to be jointed to a further element of the assembly and a non-curable filler is packed into a space formed between the bent extension and said further element.

27. A system according to any one of claims 1 to 21 wherein for each assembly the thin metal plate is in two parts each having an outwardly bent portion at each of two opposed edges thereof, said bent portions of one part being slidably interconnected with the outwardly bent portions of the other part by means of a joint member and the space between the two portions and the joint member being charged with a filler.

28. A heat-insulation system substantially as hereinbefore described with reference to Figures 1 and 2 or to Figures 1, 3 and 4, Figures 1, 5 and 6, Figures 1 and 7, Figures 1, 8 and 9 or Figures 1, 10 and 11 of the accompanying drawings.

29. A heat-insulating assembly for use in the system of any one of the preceding claims and comprising a layer of a foamed synthetic resin material, a deformable layer bonded to the foamed layer and a thin metal plate bonded to said deformable layer.

30. A heat-insulating assembly according to claim 29, and substantially as hereinbefore described.

31. A heat insulator for pipe lines for transportation of low temperature fluids which comprises a plurality of longitudinally divided hollow cylindrical heat-insulating units assembled to tightly cover the outer periphery of said pipe lines, characterised in that each heat-insulating unit is composed of a heat-insulating panel element of a circular arc in cross-section made of a foamed synthetic resin overlaid and integrally combined with an elastic sheet capable of absorbing stress caused by shrinkage of said heat-insulating panel element at low temperature and a thin metal plate placed on the outer surface of said elastic sheet and integrally combined therewith and that a sealing means is applied to the longitudinal and transverse joint contact surfaces of the adjacent heat-insulating units.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1979. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.